Morphodynamic Feedbacks during Vegetation Colonization of Tideflats

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LONG-TERM GOALS

The long-term goal of this effort is to understand interactions and feedbacks between biotic and physical process in tideflat morphodynamics. Investigated biotic processes consist primarily of vegetation colonization of tideflats. Physical process include those related to hydrodynamics, such as flow, sediment transport, salinity regime, inundation period, wave/storm disturbance, flood disturbance.

OBJECTIVES

1. To describe early vegetation colonization process in sandy tideflats. This would include determining rates of change, vegetation species involved, successional patterns (if any), and changes in tideflat biophysical structure, e.g., canopy density and height (in anticipation of these parameters being used in hydrodynamic models).

2. To discern physical controls on the colonization process, e.g., topography, sediment quality, hydrodynamics, salinity regime.

3. To discern physical consequences of vegetation colonization, e.g., direct and indirect topographic responses, including possible channel formation or stabilization and changes in sediment quality.

APPROACH

The project approach includes GIS change analysis, RTK-GPS topographic surveys, a space-for-time substitution sampling design, quantification of vegetation and sediment quality, and development of conceptual and statistical models of colonization processes and consequences. GIS change analysis was used to identify patterns and rates of channel change and vegetation development. It included analysis of orthophotos from 2004, 2006, 2007, and 2009 with pixel resolution ranging from 15cm to 45cm. RTK-GPS topographic surveys identified the topographic circumstances that characterize the locations of various species of marsh vegetation, on new islands as well as reference marshes. Additionally, these surveys (at 0.25 to 1.0 m grid resolution depending on island size, and 2 cm horizontal, 3 cm vertical accuracy) identified topographic features and patterns associated with colonizing vegetation, e.g., U-shaped scour channels and

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island lee deposition tails (Fig. 1). GIS will be used to generate TIN representations of island topography along with the adjacent tidal flat.

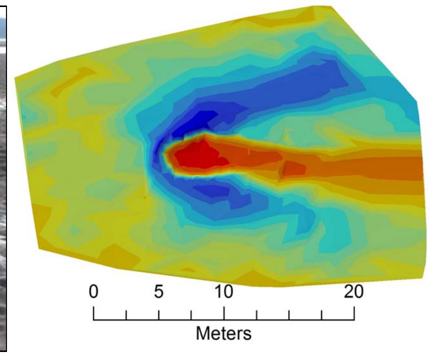

Figure 1. U-shaped scour and deposition tail (smooth ridge to right of island) associated with new Schoenoplectus americanus island at low tide. Survey rod in foreground = 1.5 m. Dominant flow is from left to right. To the right is a TIN model of the same island, where cold – warm colors represent low – high elevations. The U-shaped scour pool is in blue; the vegetated island is in red; the depositional sediment tail is in orange.

WORK COMPLETED

The project focused on small, incipient, marsh islands in tidal flats near the outlet of the principal distributary of the North Fork Skagit River (Fig. 2). Most of these islands are located in a region where the course of the distributary outlet has recently been very dynamic. RTK-GPS surveys were made of 8 incipient marsh islands ranging in size from $0.64m^2$ to $1180m^2$. Work included digitizing the sandflat tidal channels in the 2006, 2007, and 2009 orthophotos in this area, RTK-GPS survey of marsh and newly colonized island elevation and dominant vegetation (a robust data set of 925 data points for vegetation collected, in addition to the 660 vegetation data points collected last year), development of TIN representation of island and adjacent tide flat topography, and continued development of a conceptual model. Additionally, we coordinated project logistics with other Tide Flats DRI investigators staging out of the Swinomish Reservation (Brit Raubenheimer, Steve Elgar, and their staff/students from WHOI. Analysis and synthesis of results is ongoing.

Figure 2. General location of the study area (yellow rectangle), relative to the principal distributary of the North Fork Skagit River. Photo is from the spring, 2009.

RESULTS

Historical aerial photos from 1956 to 2006 (eight photos: 1956, 1965, 1972, 1980, 1990, 2000, 2004, 2006), without exception, show the study area distributary continuing straight on its course from the tidal marsh across the tidal flats. However, in 2007 the channel suddenly changed course at a nearly right angle to the west (Fig. 3). Observing eight photos without a significant change in channel course is probable ($P > 0.10$) only if the straight course occurs at least three times more frequently than the westward-bending course. The likely cause of the sudden shift in the course of this distributary appears to be a large windstorm on 15-16 November 2006 which sustained winds from the south-south east (148-153 degrees) of 80 to 100 km/h for 10 hours, with gusts up to 115 km/h. River flow during this storm was 2-3 times mean annual flow. Most of the incipient marsh islands investigated in this study are located in this area of recent channel dynamics (Figs. 4). Island topography has varied with the shifting course of the study area distributary (Fig. 5). The island tails, on the downstream side of the island, are formed by accumulations of flow-borne sediment deposited in the lee of the islands. Thus, these tails are indicators of recent dominant flow directions. The islands in this dynamic area have acted like weather vanes; the depositional sediment tails have shifted direction with shifting channel courses and flow direction.

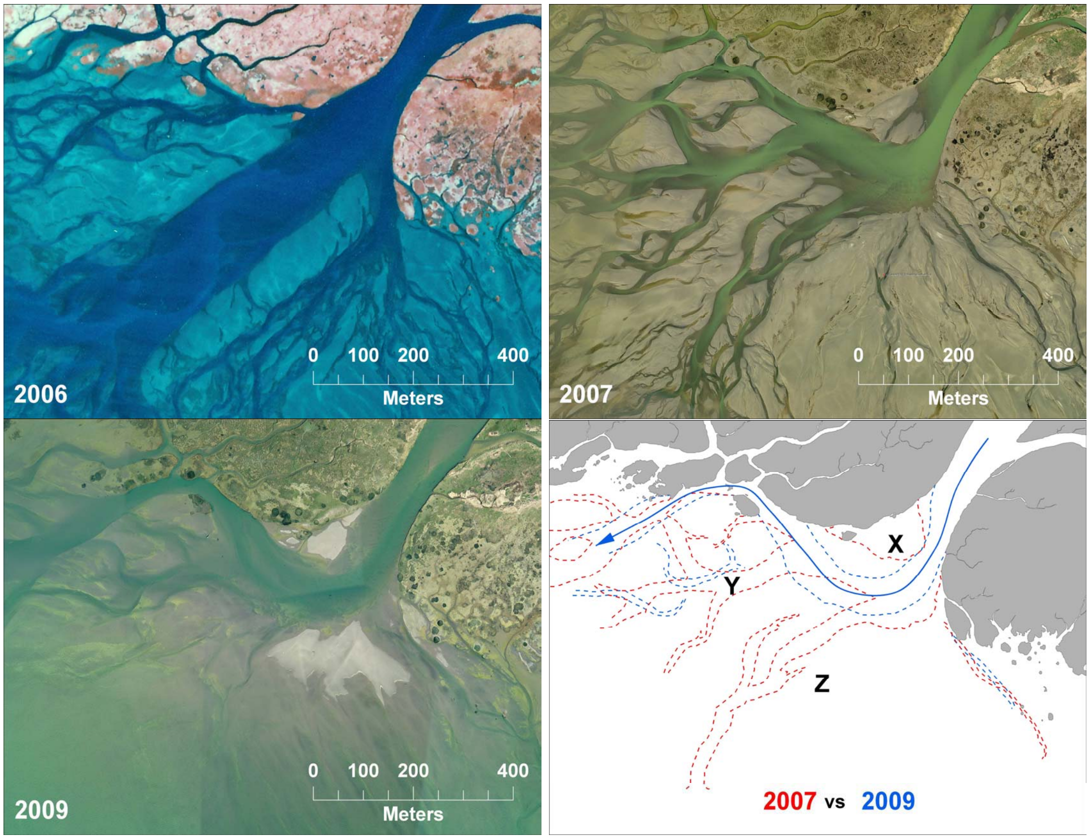

Figure 3. Comparison of the course of the study area distributary across the tidal flats. North is to the top of each frame. The main course of the distributary flows straight toward the SW in 2006, but bends to the west in 2007. The lower right frame illustrates growth in a point bar (X) from 2007 to 2009, which caused the channel bend curvature to tighten and the channel bend to migrate slightly. Digitized channels are limited to larger tide flat channels. Secondary tide flat channels diminish in some areas (Y) and disappear entirely where the main course of the distributary was located in 2006 and earlier years (Z). Note high elevation of dry sandy areas in the 2009 photo, as indicated light gray color in the point bar and opposite bank, indicating significant accumulation of sediment in these areas.

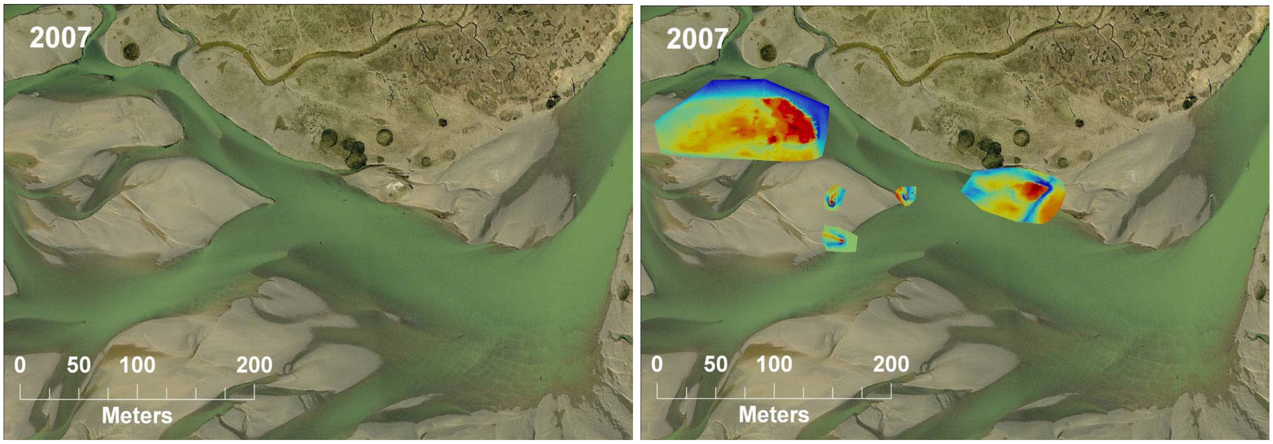

Figure 4. Five of eight study islands are located in the area of river distributary dynamism. TIN models of island topography (right frame); cold – warm colors represent low – high elevations. Note that the second island from the right is located precisely at the apex of a sandbar (compare with left frame), suggesting the resistance provided by this vegetated point facilitated a split in channel flow.

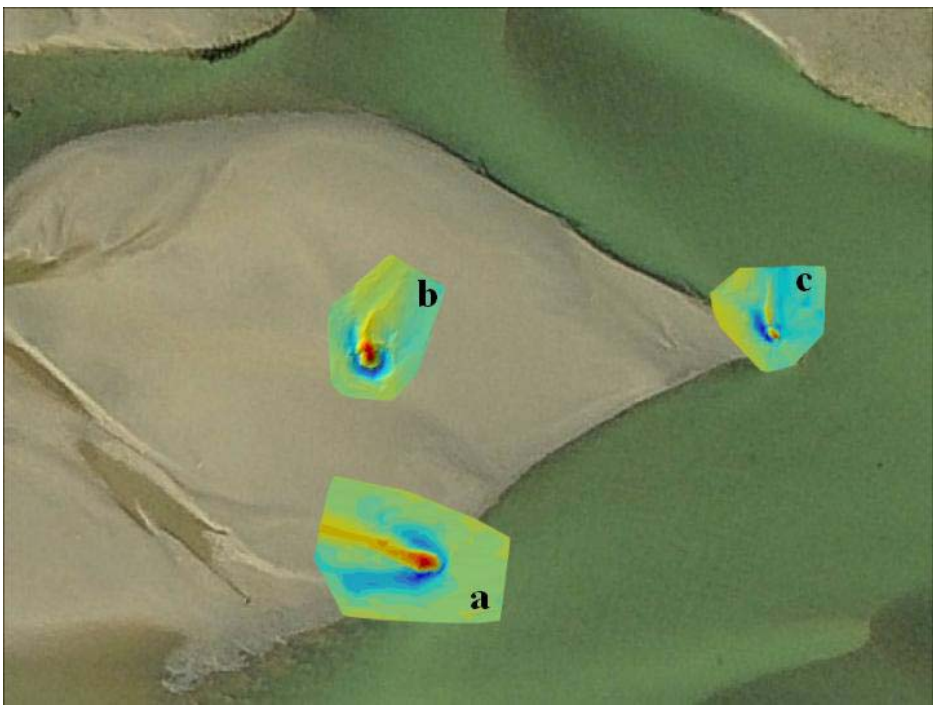

Figure 5. Three weather-vane islands – close-up of the central portion of Figure 3. The background photo is 2007. Island "a" was surveyed in 2008; the direction of its depositional tail and the location of its scour pool refleclect a transition in flow direction from 2007 to 2008. Island "b" was not surveyed in 2008, but its less prominent tail and scour pool were situated similarly to those for island "a". In 2008, islands "a" and "b" were on a sand flat at low tide with the main distributary channel to their right. Island "c" was in the center of the channel and was a navigation hazard. Islands "b" and "c" were surveyed in 2009 when the distributary had shifted so that islands "a" and "b" were in the channel at low tide and island "c" was on a point bar. The tail for island "a" disappeared by 2009, apparently eroded by flow normal to the tail.

The depositional sediment tails on the downstream side of the islands are often being colonized by low density marsh vegetation. This is particularly evident on the larger, and presumably more stable islands whose depositional tails do not undergo frequent erosion with shifting channel courses (Fig. 6). The two largest islands studied so far have shown significant vegetation colonization, with vegetation density increasing during the course of the summer (2009). Small island also show some vegetation colonization, but the spread of vegetation appears to be solely through local vegetative growth (extension of rhizomes from the island core) rather than including colonization by independent propagules. The likelihood that larger islands have more stable depositional tails, suggests that there may be a threshold in island size at which point the feedback loop between vegetation colonization and sediment depostion becomes irresistable and a mature and relatively stable marsh becomes established.

IMPACT/APPLICATIONS

Field surveys suggest a characteristic topography is associated with new or growing marsh islands in the tideflats that are also subject to significant tidal or riverine flow. These include U-shaped scour channels at the upstream end of the new island and deposition of fine sediments at the downstream tail of the island. Similar topographic patterns have been observed in braided fluvial systems except that islands in these systems are initiated by the deposition of large logs with root wads (Gurnell et al. 2005). Another significant difference, of course, is that flow in tidal systems is bi-directional. Nevertheless, the fluvial model may be a useful analog.

The weather-vane characteristic of the islands studied here (i.e., their reponsiveness to changing channel courses and flow direction) may provide a useful field indicator of recent predominant flows. This may be useful in interpretation of remotely sensed data. Conversely, islands without depositional tails (not shown) appear to generally be distant from significant flow, which may also be a useful negative indicator.

RELATED PROJECTS

This project is related to other DRI projects (http://www.tidalflats.org/) located in the Skagit Delta, particularly those involving Jim Thomson and Chris Chickadel (Applied Physics Laboratory, University of Washington), Eric Grossman (USGS, Santa Cruz), Steve Henderson (Washington State University), and Brit Raubenhiemer and Steve Elgar (WHOI) all of whom are working in the North Fork area where much of this work has taken place.

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Gurnell AM, K Tockner, P Edwards, G Petts. 2005. Effects of deposited wood on biocomplexity of river corridors. *Frontiers in Ecolog y and Environment* **3:**377-382.

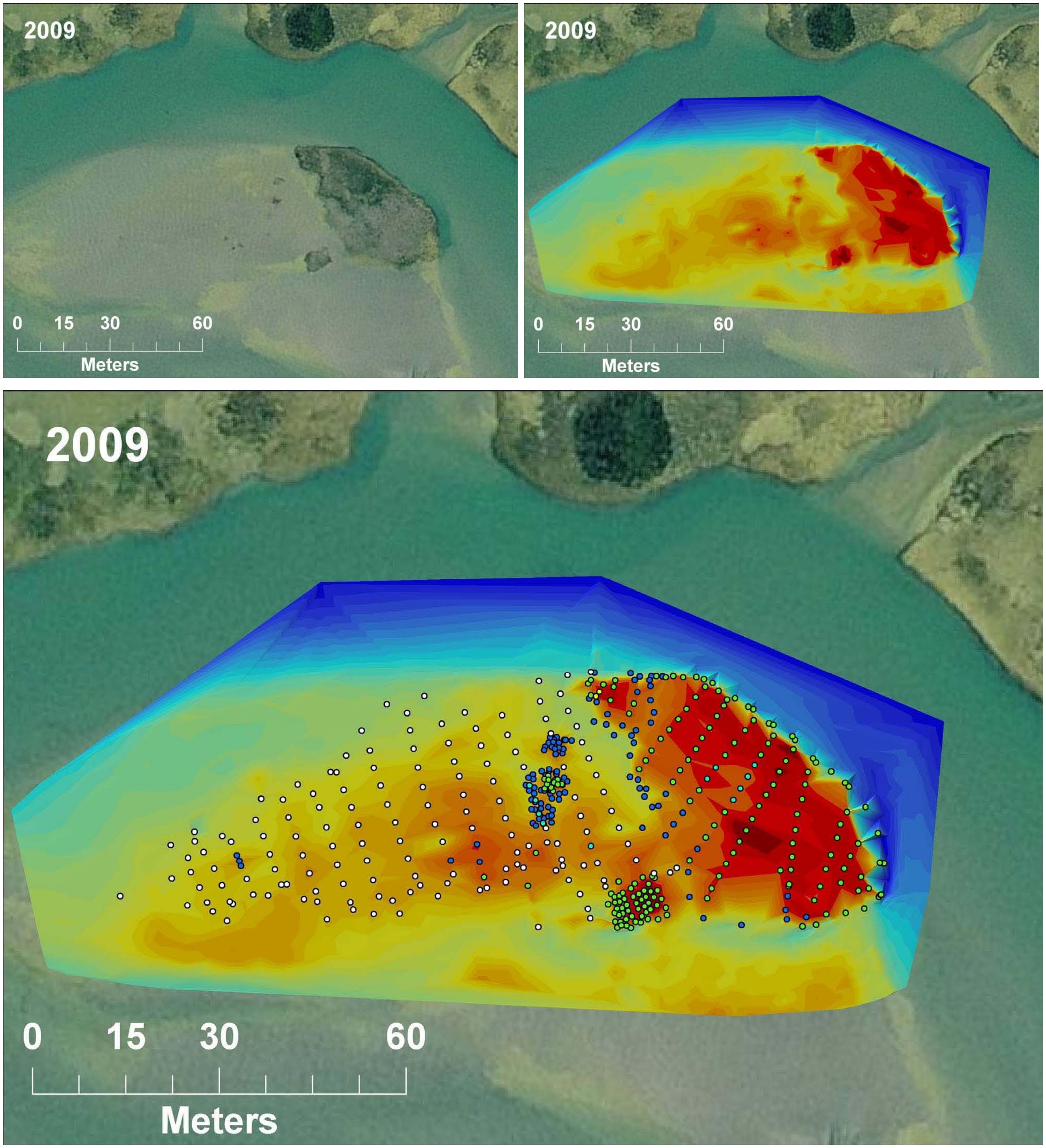

Figure 6. Island topography and vegetation. Top frames are for reference to unobstructed view of background image and TIN model. Bottom frame includes overlay of RTK-GPS points of vegetation. Green = sedge **(Carex lyngbyei)*****; blue = three-square bulrush*** **(Schoenoplectus americanus)*****; white = low density (< 3 stems per m^2) three-square bulrush, which is colonizing the sand flat. Note that colonizing vegetation is generally located on the relatively high-elevation, downstream, depositional sediment tail of the island.***